

**Before the
Federal Communications Commission
Washington, D.C. 20554**

In the Matter of	)	
	)	
Use of Spectrum Bands Above 24 GHz For	)	GN Docket No. 14-177
Mobile Radio Services	)	
	)	
Petition for Rulemaking of the Fixed Wireless	)	RM-11664
Communications Coalition to Create Service	)	
Rules for the 42-43.5 GHz Band	)	
	)	
Reassessment of Federal Communications	)	ET Docket 13-84
Commission Radiofrequency Exposure Limits and	)	
Policies	)	
	)	
Proposed Changes in the Commission's Rules	)	ET Docket 03-137
Regarding Human Exposure to Radiofrequency	)	
Electromagnetic Fields	)	
	)	

REPLY COMMENTS OF NYU WIRELESS

TABLE OF CONTENTS

<u>Heading</u>	<u>Page #</u>
Summary	2
NYU WIRELESS	3
Key Issues	5
Priority of Possible FCC Action	5
International Harmonization	15
Spectrum Above 100 GHz	23
Conclusions	31

SUMMARY

The *Notice* in this proceeding and its 176 questions raised a great number of issues, and the commenting parties addressed many of them. NYU WIRELESS addressed two issues that were not addressed by any other party as of the drafting of these *Reply Comments*: international competitiveness issues, and RF safety standard issues^{1 2} unique to mobile millimeter wave (“mmWave”) technology. In these *Reply Comments*, we focus on three issues that we believe are essential. These are 1) the priority and timing of future FCC action on mmWave mobile technology and service rules; 2) the role of international harmonization issues in these deliberations; and 3) the opening up of spectrum, including that used by passive astronomy above 100 GHz.

¹ mmWave mobile equipment does not raise any special dangers to users. But as the *Comments* point out, the issue of adaptive antennas close enough to a user, such that the user is in the near field of the transmitter, raises new measurement and regulatory issues with respect to verifying that the equipment complies with appropriate safety limits. See: “Safe for Generations to Come: Considerations of Safety for Millimeter Waves in Wireless Communications,” by T. Wu, et. al, IEEE Microwave Magazine, Vol. 16, No. 2, March 2015, pp. 65-84.

² However, in an *ex parte* notice filed after the comment date, Sony pointed out that different measurement methods may be needed above 6 GHz and that the Commission should not “foreclose the possibility of highly directional antennas” in these higher bands. They also pointed out the 5.5 dB discontinuity at 6 GHz when converting from SAR to PD methods, forcing a regulatory reduction in allowable maximum power. *Ex parte notice*, Sony Electronics Inc., Jan. 30, 2015 (<http://apps.fcc.gov/ecfs/comment/view?id=60001012898>).

NYU WIRELESS

NYU WIRELESS is a research center within New York University (NYU), founded in 2012 as one of the world's first academic research centers to combine wireless engineering, computing, and medical applications. But NYU is not new to the field of telecommunications, and in fact was a pioneering creator of the telecommunications era. Samuel F. B. Morse, the inventor of the telegraph and the Morse Code, taught at NYU in its earliest days from 1832 to 1841, the period when he conceived the telegraph and extended the technology to a range of 16 km. He continued his association with the University until just prior to his death in 1872.³

NYU's Polytechnic School of Engineering is the nation's second oldest private engineering school and is descended from Brooklyn Polytechnic Institute. It includes the former Weber Research Institute (known prior to 1985 as the Microwave Research Institute – "MRI"), founded in 1945 by Ernst Weber at Polytechnic Institute as one of the world's first research centers on applications of microwave technology. MRI's annual symposia between 1952 and 1976 were key microwave technologies conferences, and their proceedings are a key set of archives of the pioneering research of that era.⁴ Today, NYU's Polytechnic School of Engineering is home to the Brooklyn 5G Summit, an annual gathering of global wireless research and business leaders.

³ http://en.wikipedia.org/wiki/Samuel_Morse
http://en.wikipedia.org/wiki/New_York_University
http://www.nyu.edu/greyart/information/Samuel_F_B_Morse/body_samuel_f_b_morse.html

⁴ http://en.wikipedia.org/wiki/Weber_Research_Institute#Publications

NYU WIRELESS was founded by Prof. Theodore (Ted) Rappaport⁵ who, earlier in his career, founded two academic wireless communications research centers at Virginia Tech⁶ and The University of Texas at Austin⁷. These centers have produced hundreds of MS and Ph.D. engineers who are employed by, and in many cases have built and led, the wireless communications industry. NYU WIRELESS involves more than 100 students and 20 faculty members, and combines NYU's Polytechnic School of Engineering with NYU's Medical school and the Courant Institute, offering a depth of interdisciplinary expertise for the creation of new knowledge in wireless communications, computing, and medicine.

Most importantly for this proceeding, NYU WIRELESS has been a pioneer in research in terrestrial radio propagation, communication system design, and antenna technology at the millimeter wave frequencies that this proceeding deals with. With funding from the National Science Foundation⁸ and with industrial funding provided by the NYU WIRELESS Industrial Affiliates program⁹, NYU WIRELESS researchers have been conducting research in propagation measurements, radio channel modeling, system capacity analysis and simulation, antenna design, network design, and RF safety measurements and modeling at millimeter wave (mmWave) frequencies. Many other research activities not related to this NOI are also underway as a routine part of NYU WIRELESS.

⁵ http://en.wikipedia.org/wiki/Theodore_Rappaport
<http://theinstitute.ieee.org/people/profiles/theodore-rappaport-at-the-forefront-of-5g>

⁶ <http://wireless.vt.edu>

⁷ <http://www.wncg.org>

⁸ Recent NSF grants include:

Award Number 1320472 - NeTS Small: Collaborative Research: Exploring the 60 GHz Spectral Frontier for Multi-Gigabit Wireless Networks — Start Date 9/1/13

Award Number 1302336 - NeTS Medium: Massive Mobile Broadband Communications with Millimeter Wave Picocellular Networks — Start Date 9/1/13

Award Number 1237821 - PFI-AIR: Architectures for the Future Cellular Networks — Start Date 7/1/12

⁹ AT&T, Ericsson, Huawei, Intel, Keysight Technologies (formerly Agilent Technologies), L-3, National Instruments, Nokia, Qualcomm, Samsung, SiBeam, and Straightpath
(<http://nyuwireless.com/industrial-affiliates/>)

KEY ISSUES

Priority of Possible FCC Action

The *Notice* clearly stated that the Commission does not see mmWave mobile as an alternative to the use of lower bands already allocated to CMRS, or as an alternative to reallocation of lower frequency bands that are in the process of being implemented.¹⁰ Most commenting parties, including NYU WIRELESS, explicitly agreed with this need for lower frequency bands, saying that such allocations are essential, and no comments questioned the continuing requirement for CMRS to access present and expected lower frequency bands. However, there was disagreement on the urgency of acting on service rules¹¹ for mmWave mobile and the prioritization of action on mmWave with respect to other proceedings that are in the process of increasing CMRS access to spectrum below 3 or 6 GHz.

Many major wireless carriers, such as Verizon, have stated publicly that they will see “significant and pervasive network constraints” due to the present lack of spectrum, and that the future projections of user requirements provides some urgency for the FCC¹² to make mmWave spectrum available. While the recent results of Auction 97 have increased the amount of spectrum available for CMRS use, the increment is negligible compared to what is available in the mmWave bands, where mobile allocations are now lying fallow due to lack of FCC service rules.

¹⁰ *Notice of Inquiry*, Docket No. 14-177, Oct. 17, 2014, (“*NOI*”) at para. 2.

¹¹ All the bands under discussion already have both Fixed and Mobile allocations, so no new allocation action is needed, only service rule adoption.

¹² <http://www.fiercewireless.com/story/verizon-hit-lte-capacity-limit-some-markets-2013-without-new-spectrum/2012-03-05>

In recent years, unlicensed spectrum has had a beneficial impact on CMRS carriers through the offloading of traffic that would have otherwise overloaded CMRS networks.¹³ While mmWave mobile technology will not replace lower band CMRS services, its greater capacity will usher in completely new services and capabilities, and will allow carriers to offload large amounts of traffic in areas with high user demand or high user density. This will complement lower band networks, and allow them to extend their service capability over time, just as Wi-Fi offloads have helped today's networks.¹⁴ Another novel benefit of mmWave mobile systems is that the large bandwidths available will also translate into much more precision in measuring the position of users or machines. This improved accuracy for mmWave mobile users will improve E911 position location performance, and will also lead to new uses of location information that will be vital for peer-to-peer (P2P) and machine-to-machine (M2M) networks between vehicles or robots.¹⁵

Much of the technology needed to properly analyze, deploy, and install mmWave mobile communication systems already exist today, or are under development, as many commercial vendors provide design and deployment software that are regularly used by wireless providers, using site-specific propagation prediction techniques such as ray-tracing.¹⁶

A few of the commenters seemed to imply that FCC actions on CMRS spectrum

¹³ C. Na, J. Chen, T.S. Rappaport, "Measured Traffic Statistics and Throughput of IEEE 802.11b Public WLAN Hotspots with Three Different Applications", *IEEE Transactions on Wireless Communication*, Vol. 5, No. 11, November 2006, pp. 3296-3305.)

¹⁴ *Comments of Consumer Federation of America*, Docket 12-268, Jan. 25, 2013 at p. 17 (<http://apps.fcc.gov/ecfs/comment/view?id=6017160008>)

¹⁵ C. McGillem, T. Rappaport, "Infra-red location system for navigation of autonomous vehicles", *Proc. IEEE 1988 International Robotics and Automation Conference*, Vol. 2, p. 1236 - 1238 (ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=12230)

¹⁶ G. Durgin, et. al., "An advanced 3D ray launching method for wireless propagation prediction," *Proc. IEEE Vehicular Technology Conference*, May, 1997, Vol. 2, pp. 785-789.

were a “zero sum game;” that is, that any action towards mmWave allocation could be detrimental to increased spectrum access at lower frequencies, and therefore must wait for or be subordinate to those actions. Mobile Future made this point most clearly in saying:

(I)t is critical that efforts in this proceeding do not delay or supersede Commission efforts to bring lower band spectrum to market for consumers. Clearing and reallocating low- and mid- band spectrum for exclusive licensed use by commercial operators continues to hold the most promise for the continued innovation, investment, and deployment of mobile broadband networks.¹⁷

CTIA and Verizon made more ambiguous statements, but also expressed clear concern about efforts in this proceeding possibly detracting from FCC action in today’s lower UHF or microwave bands. CTIA stated,

Thus, while CTIA strongly supports the Commission’s efforts to allocate additional high frequency spectrum for mobile broadband services, the Commission should not lose sight of the paramount goal of freeing much-needed additional spectrum below 3 GHz for mobile services.¹⁸

In a similar vein, Verizon stated:

IT IS IMPORTANT TO AVOID PREMATURE ASSUMPTIONS ABOUT ABOVE-24 GHz TECHNOLOGY.(sic)

While a substantial amount of work is being done that may eventually lead to commercial uses of one or more above-24 GHz spectrum bands, it is currently unclear what technologies and business models may eventually emerge for those frequencies. The Commission should thus avoid making determinations at this time – even preliminary ones – about the appropriate regulatory framework or frameworks.... By contrast, the know-how to deploy mobile operations using more traditional mobile frequencies already exists, and consumers’ exploding need for bandwidth means that making available more “traditional” mobile spectrum needs to be the Commission’s top priority.¹⁹

All commenters mentioning lower frequency spectrum agreed that it was needed in both the short term and the long term. However, most of the commenters had a very different viewpoint than the above statements regarding the delay or subordination of mmWave regulations. Straight Path Communications, Inc., a major holder of mmWave

¹⁷ *Comments of Mobile Future*, Docket 14-177, January 15, 2015 at p. 1

¹⁸ *Comments of CTIA –THE WIRELESS ASSOCIATION®*, Docket 14-177, January 15, 2015 at p. 2

¹⁹ *Comments of Verizon*, Docket 14-177, January 15, 2015 at p. 2 (Verizon is a member of Mobile Future.)(<http://apps.fcc.gov/ecfs/document/view?id=60001013803>)

spectrum, was explicit when it said:

Straight Path urges the Commission to proceed quickly to issue one or more notices of proposed rulemaking in order to adopt regulations that will enable the mmW bands to be used for flexible use, including mobile applications.²⁰

SiBeam, a major innovator of mmWave integrated circuits and systems, proposes that the Commission move now on expanding the 60 GHz band up to 71 GHz, and on updating the 70/80 GHz rules to make them more flexible.²¹ Samsung Electronics USA and Samsung Research, America, one of the leading researchers and developers of mmWave technologies, urges that “the 28 and 39 GHz bands should be the Commission’s top priorities at this time” and that “the 60 GHz band also holds promise as a home for licensed 5G services”.²² Intel “believes both licensed and unlicensed allocations in (spectrum above 24 GHz) have potential value for future mobile communications use” and “there is a need to expeditiously assess the viability of these bands in advance of (WRC-19)”.²³

Similarly, TIA²⁴, Qualcomm²⁵, the Consumer Electronics Association (“CEA”)²⁶, and Wireless Innovation Forum²⁷ urge that the Commission move ahead in a deliberate fashion to start creating a framework for mmWave mobile use. TIA explains the

²⁰ *Comments* of Straight Path Communications, Inc., Docket 14-177, January 15, 2015, at p. 2 (<http://apps.fcc.gov/ecfs/document/view?id=60001013744>)

²¹ *Comments* of SiBeam, Docket 14-177, January 15, 2015, at p. 6 (SiBeam is a unit of Silicon Image) (<http://apps.fcc.gov/ecfs/document/view?id=60001013930>)

²² *Comments* of Samsung Electronics USA and Samsung Research, America Docket 14-177, January 15, 2015, at p. 45 (<http://apps.fcc.gov/ecfs/document/view?id=60001013807>)

²³ *Comments* of Intel, Docket 14-177, January 15, 2015 at p. 1 (<http://apps.fcc.gov/ecfs/document/view?id=60001013611>)

²⁴ *Comments* of The Telecommunications Industry Association, Docket 14-177, January 15, 2015, at p. 4 (<http://apps.fcc.gov/ecfs/document/view?id=60001013721>)

²⁵ *Comments* of Qualcomm, Docket 14-177, January 15, 2015, at p. ii

²⁶ *Comments* of The Consumer Electronics Association, Docket 14-177, January 15, 2015, at p. 11 (<http://apps.fcc.gov/ecfs/document/view?id=60001013615>)

²⁷ *Comments* of Wireless Innovation Forum, Docket 14-177, January 15, 2015, at p. 2 (<http://apps.fcc.gov/ecfs/document/view?id=60001013539>)

relationship between timely FCC action and international competitiveness:

“For reasons of maintaining global competitiveness and to encourage further innovation, the U.S. ICT industry would benefit from near-term policy development – and the increased regulatory certainty that will hopefully result – regarding various millimeter-wave spectrum bands.”

While it is tempting to think that technical developments in mmWave mobile technology would march forward for the benefit of US citizens, independent of FCC action or inaction, this is not likely to be the case. R&D in advanced technologies depends critically on capital formation, whether in a startup company or in an existing multinational vendor. In both cases, those who control funding need to see a business plan with “light at the end of the tunnel”. Those making such investment decisions do not expect certainty, but they do expect to know when market access is possible, so that market place forces can then be determined and measured, so as to evaluate whether the investment is profitable or not.

In our *Comments* filed January 13, 2015²⁸, we documented the strong (multi-billion dollar) investments and governmental support for 5G and consumer-based mmWave technologies that are occurring in many countries. Such support does not presently exist in the US. In the case of wireless technology needing non-routine FCC approvals, such as mmWave mobile, the current-day regulatory uncertainty, absent ongoing FCC deliberations on service rules for providing much needed flexibility and optional spectrum sharing, may well create regulatory risks that are prohibitively expensive in the eyes of any capital source, thus cutting off potential benefits to US consumers and US companies by preventing competitive market forces to work in this country.

As CEA wrote in their comments,

²⁸ *Comments* of NYU WIRELESS, Docket 14-177, January 13, 2015, at p. 8-12 (<http://apps.fcc.gov/ecfs/document/view?id=60001013322>)

Waiting to issue a Notice of Proposed Rulemaking until industry is ready to deploy mmW technologies risks foreclosing opportunities. Consumer demand is growing too fast to have such a reactive approach and its associated delay. At the same time, given the rapid pace of development, the unique nature of the bands and the wide variety of anticipated uses, the FCC should refrain from foreclosing options too soon.²⁹

Qualcomm “encourages the FCC to promptly issue band-specific Notices of Proposed Rulemaking” for several bands, and to extend the 60 GHz unlicensed band to 71 GHz.³⁰

In our comments, we discussed at length international competitiveness issues and described how many other countries that are economic competitors of the US are actively subsidizing mmWave mobile research and coupling this financial support with supportive representation in ITU and standards bodies for the technologies that are “national champions”.³¹ This is not the US system for developing and regulating innovative technologies. US entities can usually compete on this uneven playing field, but only if the Commission is supportive and deliberate in giving their developments a reasonable expectation of timely access to US markets, which in turn will lower barriers for capital formation.

None of the commenting parties seeking to delay Commission deliberations on mmWave mobile usage give *any* statutory citations or Commission precedents justifying such action. However, we *can cite specific provisions* of the Communications Act of 1934 as amended, that both *authorize* and *urge* timely deliberations. § 7(a) states:

It shall be the policy of the United States to encourage the provision of new technologies and services to the public. Any person or party (other than the Commission) who opposes a new technology or service proposed to be permitted under this chapter shall have the burden to

²⁹ *Comments* of CEA, Docket 14-177, January 15, 2015, at p. 11 (<http://apps.fcc.gov/ecfs/document/view?id=60001013615>)

³⁰ *Comments* of Qualcomm, Docket 14-177, January 15, 2015, at p. ii (<http://apps.fcc.gov/ecfs/document/view?id=60001013664>)

³¹ *Comments* of NYU WIRELESS, Docket 14-177, January 13, 2015, at p. 8-12 (<http://apps.fcc.gov/ecfs/document/view?id=60001013322>)

demonstrate that such proposal is inconsistent with the public interest.³² (Emphasis added)

The longstanding provisions of § 303(g) direct the Commission to:

Study new uses for radio, provide for experimental uses of frequencies, and generally encourage the larger and more effective use of radio in the public interest;³³ (Emphasis added)

In the Docket 09-157 *Notice of Inquiry* the Commission stated

(W)e recognize the success of certain regulatory policies in promoting innovation, we are aware that Commission policies and processes can also hinder the progress of innovation and investment. At times, we have seen innovators subjected to lengthy regulatory processes - such as debates over what constitutes harmful interference or how to fit a new spectrum use within our framework of rules -that can be an obstacle to progress in the wireless arena³⁴

Thus, the Commission actually has a *statutory mandate* to act on new technologies, not to delay consideration, as has been urged by a few of the commenters. No commenters provided any evidence for why immediate rulemaking that provides flexible use of mmWave spectrum by existing incumbents and new entrants would be against the public interest. In fact, an overwhelming number of commenters specifically urged the Commission to act swiftly for public benefit. The Commission has recognized (as shown above) that long debates over new technology can actually be “an obstacle to progress”. Given the well-documented and ever-increasing demand in user bandwidth, and a persistent ‘digital divide’ that exists today throughout the US between rural and urban centers, the FCC must act quickly to provide regulatory access to mmWave spectrum, and not delay or make subservient such activities in deference to spectrum policy below 6 GHz.

³² 47 U.S.C. 157(a)

³³ 47 U.S.C. 303(g)

³⁴ *Notice of Inquiry*, Docket 09-157, Aug. 27, 2009, at para. 5 (https://apps.fcc.gov/edocs_public/attachmatch/FCC-09-66A1_Rcd.pdf)

We can cite an important precedent of another time when other parties advocated the type of regulatory delays and uncertainties that some of commenters have requested in this proceeding: in the comments of Docket 81-413 in the early 1980s, many of the commenters stated³⁵ that spread spectrum technology was not mature and the Commission should delay any new rules until it matured. Fortunately, the Commission did not heed these requests, as the resulting rules (now codified as § 15.247³⁶) created the unlicensed ISM bands that became the underlying foundation for Wi-Fi, Bluetooth, ZigBee and many other products that have literally changed our world, benefitting US citizens and many US companies who were the early leaders in creating the technologies and applications for this booming industry segment.³⁷

Therefore, we urge the Commission to continue its movement towards the authorization of mmWave mobile service, consistent with protecting the rights of incumbent licensees and federal users, allowing current license holders to rapidly explore new business partnerships and service offerings that would allow spectrum to be put to use immediately for the benefit of the US consumer, and encouraging new entrants through additional spectrum allocations through both licensing (perhaps through auction) and unlicensed allocations.

We note that in its *Comments*, Verizon supports the idea of “granting (incumbents) flexible use rights, along with flexibility to transfer the spectrum” in the case of bands where there are “relatively few incumbents”.³⁸ We believe that the 24 GHz band, LMDS (28 GHz) band, and the 39 GHz band clearly fit the “relatively few incumbents”

³⁵ See *First Report and Order*, Docket 81-413, May 9, 1985 at para. 5-18

³⁶ 47 C.F.R. 15.247

³⁷ K.Carter, A. Lahjouji, and N. McNeil, “Unlicensed and Unshackled: A Joint OSP-OET White Paper On Unlicensed Devices and Their Regulatory Issues”, FCC/OSP Working Paper 39 (May 2003) (http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-234741A1.pdf)

³⁸ *Comments* of Verizon, Docket 14-177, January 15, 2015 at p. 4

category, while the 70/80 GHz band clearly does not. The 37/42 GHz bands and the 64-71 GHz bands have no service rules, and thus no incumbents, while the 57-64 GHz band is unlicensed Part 15 band and has no proposed licensed service rules. Action to expand the rights of licensees in one or more of the bands with incumbents would be straightforward due to the single user geographic nature of the present licenses.

If mmWave mobile regulations are enacted, as many commenters have recommended, but if market adoption or cost-effective technology takes longer than expected, a carefully crafted “fail-safe” policy can protect the incumbent licensees from penalties (such as the loss of their license) as they earnestly attempt to ramp spectrum usage. The fail-safe policy, combined with flexible, encouraging regulations, will remove worries and encourage bold thinking to bring new capacity on line to consumers.

On January 16, 2015 the Commission’s UK counterpart, Ofcom, issued a “Call for Input” on “Spectrum above 6 GHz for future mobile communications” that is somewhat analogous to the current FCC *NOI*.³⁹ The simultaneity of this Ofcom action shows the timeliness and global importance of this FCC initiative. We also note the schedule that Ofcom has announced for itself:

³⁹ Ofcom (UK), *Call for Input on Spectrum above 6 GHz for future mobile communications* (“Ofcom Inquiry”), January 16, 2015 (http://stakeholders.ofcom.org.uk/binaries/consultations/above-6ghz/summary/spectrum_above_6_GHz_CFI.pdf)

Next steps

- 4.1 Following the close of this Call for Input we expect to publish a summary of responses and an update in Q2 2015. The update will also draw on the related work we are undertaking (discussed in section 1), including technical research and the technology event which we are planning to hold in March 2015, and our ongoing work on the future demands of other sectors that use spectrum above 6 GHz.
- 4.2 The output of the Call for Input and related work will also help inform our contribution to forthcoming international discussions, including the relevant European preparatory meetings for WRC-15 at which the scope of a future WRC-19 agenda item on bands above 6 GHz will be considered. The output will also help to inform the positions we take at WRC-15 itself and in any other European or international discussions addressing future requirements for 5G.
- 4.3 Looking further ahead we will consider if and when it would be appropriate to publish a strategy consultation on bands above 6 GHz (similar to our Mobile Data Strategy that looked at bands below 6 GHz), that consider the issues for specific potential bands in more detail. Such a consultation is more likely to be after WRC-15, when the scope of any future agenda on bands above 6 GHz item is clearer.

Figure 1: “Next Steps” Section of Ofcom Inquiry⁴⁰

We suggest the FCC commit itself to a schedule comparable to Ofcom’s, which anticipates that early decisions and actions will occur in the “2Q of 2015”, particularly since the Commission started this proceeding before Ofcom started its inquiry.

On February 3, 2015, Cisco released⁴¹ the latest update to its VNI Mobile Forecast that has been used previously by the Commission as a reference⁴² for expected growth rates. Here are some key data points from this recent update for the 2014 to 2019 period:

“In the United States, mobile data traffic will grow 7-fold from 2014 to 2019, a compound annual growth rate of 47%.

In the United States, mobile data traffic will reach 3.6 Exabytes per month by 2019 (the equivalent of 904 million DVDs each month), up from 531.7 Petabytes per month in 2014.

In the United States, mobile data traffic will reach an annual run rate of 43.4 Exabytes by 2019, up from 6.4 Exabytes in 2014.

⁴⁰ *ibid* at p. 18

⁴¹ <http://newsroom.cisco.com/press-releasecontent?type=webcontent&articleId=1578507> This update confirms growth data from Cisco, Intel and Ericsson that we have previously reported in “Millimeter Wave Wireless Communications: The Renaissance of Computing and Communications”, Keynote address by T. Rappaport at 2014 International Conference on Communications, Sydney, Australia (June 13, 2014) (http://icc2014.ieee-icc.org/speakers_28_4101586138.pdf)

⁴² FCC, *Connecting America – The National Broadband Plan*, March, 2010 at p. 76 (<http://transition.fcc.gov/national-broadband-plan/national-broadband-plan.pdf>)

In the United States, mobile traffic per mobile-connected end-user device will reach 7,815 megabytes per month by 2019, up from 1,503 megabytes per month in 2014, a CAGR of 39%.

In the United States, mobile traffic per mobile connection (including M2M/LPWA) will reach 3,393 megabytes per month by 2019, up from 1,325 megabytes per month in 2014, a CAGR of 21%.

In the United States, mobile traffic per user will reach 11,510 megabytes per month by 2019, up from 1,960 megabytes per month in 2014, a CAGR of 41%.

In the United States, mobile traffic per capita will reach 10,782 megabytes per month by 2019, up from 1,648 megabytes per month in 2014, a CAGR of 46%.⁴³

Clear action by the FCC can stimulate R&D and the capital formation for R&D, and business development, so as “to make available, so far as possible, to all the people of the United States... a rapid, efficient, nationwide, and world-wide wire and radio communication service with adequate facilities at reasonable charges”.⁴⁴ The US does not have the government financial support of 5G technology development that our national economic competitors do, but with assurance of timely regulatory decisions, including positive positioning at WRC 15, US entities can raise private capital to compete with international competitors. Lengthy regulatory uncertainty in the US, on the other hand, will favor overseas developers of wireless technology and hurt US competitiveness and its citizens.

International Harmonization

International harmonization was another area where there was a major dichotomy among the commenting parties. Most commenting parties mentioned this issue, and all who mentioned it agreed that it would be a positive factor in the implementation of

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http://www.cisco.com/c/dam/assets/sol/sp/vni/forecast_highlights_mobile/index.html?CAMPAIGN=Mobil eVNI2015&COUNTRY_SITE=us&POSITION=social+media+organic&REFERRING_SITE=SocialMedia&CREATIVE=Social+Media+to+VNI+highlights+tool#~Country

⁴⁴ 47 U.S.C. 151

mmWave mobile systems. However, there were key differences in the comments on the absolute importance of international harmonization in US spectrum policy for mmWave mobile use.

While the ITU *Radio Regulations* are a treaty obligation of the US Government, these regulations do not require a signatory to implement every band allocated to the Mobile Service, nor do ITU regulations require a specific standard over-the-air interface in any country. Further, Radio Regulation 4.4 allows ITU signatories even to implement radio service not in compliance with international allocations, if that service does not cause interference to other signatories who are in compliance.⁴⁵ Due to the propagation characteristics of mmWave bands using directional, steerable antennas, interference to terrestrial systems in neighboring nations or even nearby nations is practically impossible. (However, interference to satellite systems in shared bands does require attention, but we believe these will be easy to manage, as discussed in our *Comments*.) Thus, while harmonization is generally positive, it is not a treaty requirement for the FCC -- although in Europe, it is a requirement for European Union member countries.

Among the parties pressing for global harmonization is Motorola Mobility, who argues that:

“Further investigation of candidate frequency bands and development of technical standards should be completed before it would be fruitful for the Commission to consider adopting potential technical rules or licensing regimes for spectrum above 24 GHz.”⁴⁶

Similarly, Huawei Technologies, Inc. (USA) states that:

⁴⁵ ITU Radio Regulation 4.4:

“Administrations of the Members shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations given in this Chapter or the other provisions of these Regulations, except on the express condition that harmful interference shall not be caused to services carried on by stations operating in accordance with the provisions of the Constitution, of the Convention and of these Regulations.”

⁴⁶ *Comments* of Motorola Mobility, Docket 14-177, January 15, 2015, at p.5 (<http://apps.fcc.gov/ecfs/document/view?id=60001013794>)

“To meet the additional spectrum requirements for 5G, Huawei strongly believes that spectrum assignments, including those in the mmW bands, must be harmonized globally.”⁴⁷

4G Americas adds that they “note that global harmonization will be key in 5G deployment”.⁴⁸ Intel believes:

“global harmonization is an essential element in the success of future 5G mobile broadband systems as it has been for the previous generations. The benefits of economies of scale and products that could roam globally are well known.”⁴⁹

But Qualcomm advocates a more nuanced approach stating:

“The Commission should favor global harmonization in the millimeter wave bands used for mobile operations where possible because it lowers equipment costs, particularly antenna and RF transceiver complexity, and also offers end users a more predictable QoE when traveling outside the U.S.

At the same time, the desire for global harmonization should not stop the FCC from taking action to define a new mobile service and providing flexibility to licensed incumbents in the identified millimeter wave bands, despite the fact that other countries have no plans to do so; setting rules to support mobile operations in the millimeter bands will help to spur innovation, which is clearly in the public interest.”⁵⁰ (Emphasis added)

Pursuing international harmonization as an absolute requirement would strip the Commission of its role as the sovereign regulator of nonfederal government spectrum use in the US, and would make all mmWave mobile usage subject to lengthy deliberations in ITU and standards groups before this promising technology can reach the public.

We urge the middle road, advocated by Qualcomm above, where the Commission would start designating some bands for mmWave mobile use in the immediate future, while working with the ITU to bring about harmony where possible.

Full international harmonization of mmWave bands for mobile use will be difficult

⁴⁷ *Comments of Huawei Technologies, Inc. (USA)*, Docket 14-177, January 15, 2015, at p. 15 (<http://apps.fcc.gov/ecfs/document/view?id=60001013821>)

⁴⁸ *Comments of 4G Americas*, Docket 14-177, January 15, 2015, at p.6 (<http://apps.fcc.gov/ecfs/document/view?id=60001013849>)

⁴⁹ *Comments of Intel*, Docket 14-177, January 15, 2015, at p. 39 (<http://apps.fcc.gov/ecfs/document/view?id=60001013611>)

⁵⁰ *Comments of Qualcomm*, Docket 14-177, January 15, 2015, at p. 16 (<http://apps.fcc.gov/ecfs/document/view?id=60001013664>)

in the US for several reasons. The US faces many key national security threats as can be seen from recurring events reported in the news media. The US has both the largest military in the world, but also the most ICT-intensive military in the world. These national security issues place constraints on spectrum access for CMRS systems that are different than those in other countries.

While it would be clearly desirable to have full international harmonization on bands used for mmWave mobile, it may not be possible in the US context. While this would be an inconvenience to users who travel among many countries, commonality among most bands would limit its impact just as today's CMRS equipment has many bands with international harmonization, but not all bands.

Furthermore, as has happened in past wireless developments in new frequency bands, the US could actually lead the global movement to certain mmWave bands by immediately establishing mobile service in some or all of the existing bands cited in the *Notice* (as it did when it created rules to allow the use of unlicensed wireless products in the ISM bands in the 1980s, and the 60 GHz unlicensed band and CMRS personal communication system bands in the 1990s). Thus, timely access by the US in some of the bands under consideration in this proceeding could help continue US leadership in spectrum policy and wireless usage, while addressing concerns specific to the US, like sharing with military spectrum use and the traditional greater emphasis on passive service (astronomy community) needs than in some other countries.

While we cannot dispute the fact that global spectrum harmonization is valuable for global market acceptance and low cost products, US spectrum policy is a great equalizer to the billions being spent in other countries on 5G and mmWave technologies. The US

should move quickly to keep the US abreast of this technology through spectrum policy.

Finally, it is worth noting that for a given percentage bandwidth, carrier frequency range is much greater at mmWave than in today's CMRS allocations. For example, a +/- 6.5% difference in frequency from a center frequency of 29.5 GHz covers the entire band spread between 27.5 and 31.25 GHz, the entire span of the LMDS allocation. Thus, while different regions or countries may have slightly different frequency band allocations, a low-cost mobile device could be made to work well over a wide range (several GHz) of frequency. Also, RFIC technologies exist today that allow low cost circuits and antennas to be built over a vast range of mmWave frequency bands.⁵¹ As pointed out in one of our recent publications,⁵² the proportional difference in frequency range between 28, 39, and 72 GHz is less than a factor of three, much smaller than today's proportional span of global CMRS frequencies that span 500 MHz to 3.5 GHz – a factor of seven.

Recent work proves that radio propagation in all three of these mmWave bands (28, 39, and 72 GHz) are quite similar with respect to large-scale and small-scale propagation characteristics when directional antennas are used, with the biggest difference in path loss occurring in the very first meter of propagation from an access point.⁵³ This important observation implies that low-cost electronics will be viable over a wide range of mmWave bands, just as is the case for today's wide range of CMRS UHF/microwave bands, making international harmonization less critical to the roll-out of mmWave technologies, *provided* there are spectrum allotments in mmWave frequencies throughout

⁵¹ T. Rappaport, *et al.*, *Millimeter Wave Wireless Communications*, Prentice Hall, 2015

⁵² T. Rappaport, *et al.*, "Millimeter Wave Mobile Communications for 5G: It will work", *IEEE Access* (May 2013).

⁵³ S. Deng, C. Slezak, G. MacCartney Jr., T. Rappaport, "Small Wavelengths – Big Potential: Millimeter Wave Propagation Measurements for 5G", *Microwave Journal*, November 2014 (<http://www.microwavejournal.com/articles/23274-small-wavelengths-big-potential-millimeter-wave-propagation-measurements-for-5g>)

the world that support similar products and applications.

After all, today there are dozens of different globally licensed bands for 4G LTE cellular service, all supported within mobile handsets through the use of chipset product offerings by various chipmakers.⁵⁴

Based on the past history of the cellular industry, and the proven similarities in propagation across a wide range of mmWave bands, chipsets for mmWave devices can be made in large quantities to support a wide range of different mmWave frequency bands in the same chip, making international harmonization less critical for commercial rollout. Much more critical to the rollout of new services and technology is prompt rulemaking by the Commission and other governments to support the use of the mmWave spectrum for mobile services.

Making the complete international harmonization of bands as an absolute goal will prevent rapid implementation of mmWave mobile in bands that are readily accessible in the US jurisdiction, and for which US manufacturers have the ability and interest to manufacture equipment for the large US market. In the recent Ofcom Inquiry into issues parallel to this proceeding, the Commission's UK counterpart both recognized the benefits of "harmonization" and its practical limits, stating

In addition to standardization of 5G technology, the other key element on which commercial deployment will depend is the identification of suitable regional, and ideally globally, harmonised spectrum allocations. Over the last few years, as part of preparation for WRC- 15 (specifically agenda item 1.1), there have been considerable international efforts to consider potential future bands for mobile broadband use below 6 GHz. Global identification of allocations in the Radio Regulations (for IMT 5), as a result of a WRC, is an important first step in supporting global adoption of a technology. However, it generally does not prescribe spectrum use at a national level, as that remains under the jurisdiction of each individual country, and is therefore not always necessary for regional harmonisation (e.g. with the EU).⁵⁵

⁵⁴ http://en.wikipedia.org/wiki/List_of_LTE_networks
<http://www.radio-electronics.com/info/cellulartelecomms/lte-long-term-evolution/lte-frequency-spectrum.php>

⁵⁵ *Ofcom Inquiry* at Section 1.10

Thus, Ofcom views globally “harmonised” spectrum as an ideal goal, *not* a prerequisite for commercial deployment, and recognizes the right of national regulators to prescribe technologies in their jurisdictions.

The bands above 24 GHz that Ofcom is initially considering (“filtered bands” in their nomenclature) are 25.25-29.5 GHz, 36-40.5 GHz, 42.5-52.6 GHz (excl. 50.2-50.4 GHz), and 55.78-76 GHz.⁵⁶

Below is a comparison of these, and the bands listed in the *Notice*.

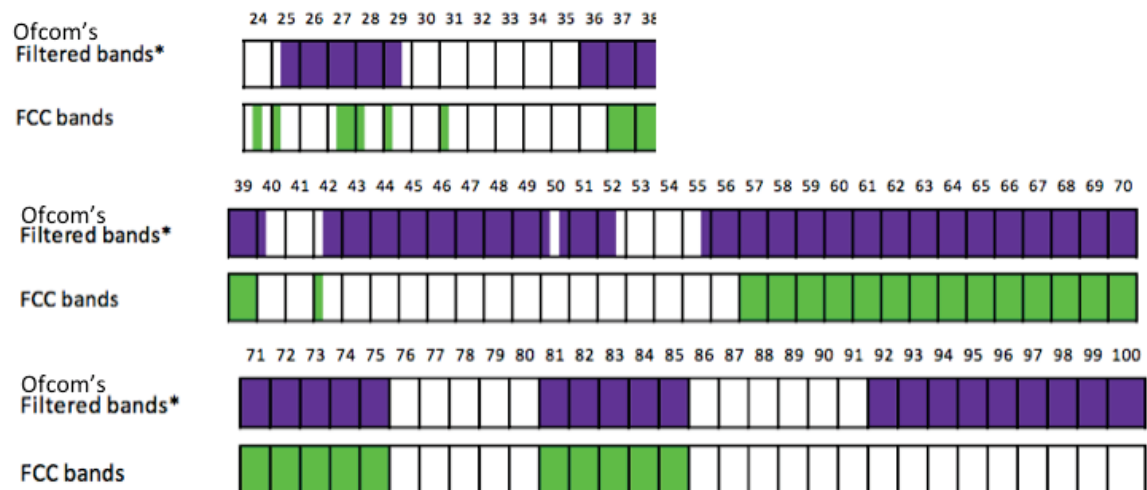


Figure 2: Comparison of bands being considered by FCC and Ofcom⁵⁷

⁵⁶ *ibid.* at Section 3.9

⁵⁷ *ibid.* at Figure 2

It can be seen that the LMDS band, 39 GHz band, 60 GHz unlicensed bands, and 70/80 GHz bands are common to both the FCC and Ofcom current inquiries. Therefore, these are good candidates for initial and immediate FCC actions.

Many of the parties advocating total international harmonization seem unaware that since the Commission's 1987 adoption of 2G rules, the technical details of CMRS air interfaces have generally been left to marketplace forces, and not regulation. The present CMRS rules focus on interference prevention, not mandatory modulation and signaling formats.⁵⁸ In many other jurisdictions, the opposite is true. We believe that the reason that 4G is presently more widely available in the US than in other jurisdictions⁵⁹ is that US carriers had the technical flexibility to implement it when they thought it was effective to serve their business needs and to meet the needs of their own customers, and not when some external multinational entity thought the time was right for its adoption.

No commenting parties have given a cogent reason why the Commission should move away from the 1987 precedent of not requiring technical standards other than interference-related ones. This policy has served the CMRS industry well for nearly 30 years, and was also instrumental in making Qualcomm a major manufacturer in the world

⁵⁸ *Notice of Inquiry*, Docket 09-157, Aug. 27, 2009, at para. 22

(https://apps.fcc.gov/edocs_public/attachmatch/FCC-09-66A1_Rcd.pdf)

"The Commission also shifted away from mandating technical standards other than those designed to control interference or to meet specified public interest objectives (e.g., ensuring the development of hearing aid compatible wireless phones). For example, analog cell phones were originally required to meet a detailed technical protocol. The Commission subsequently adopted more flexible technical rules, which in turn have enabled the introduction of second, third, and fourth generation digital wireless phones, all without the need for further Commission action."

⁵⁹ "Europe Struggles to Catch Up With U.S. on 4G Investment", *Wall Street J.*, February 21, 2014

(<http://www.wsj.com/articles/SB10001424052702304914204579396622656906700>)

"1H2014: LTE Share 33% of all Mobile Connections in the U.S. and Canada vs. 4% Worldwide,"

FierceWireless, September 04, 2014

(<http://www.fiercewireless.com/press-releases/1h2014-lte-share-33-all-mobile-connections-us-and-canada-vs-4-worldwide>)

market, even though at the time it introduced CDMA technology, most standards groups and national regulators thought CDMA was not practical for CMRS use. Qualcomm's ability to enter the US market with CDMA proved the viability of that technology, which was later used in all the world's 3G systems.⁶⁰

The FCC has before it an opportunity to bring new technology, innovation, and improved services and businesses to the American public through swift rulemaking that allows mobile use of the mmWave spectrum. International harmonization does not need to be a prerequisite in such action.

SPECTRUM ABOVE 100 GHz

The *NOI* in this proceeding has as a main caption "Use of Spectrum Bands Above 24 GHz For Mobile Radio Services," but the only bands explicitly mentioned are between 24 GHz and 86 GHz. In addition to our *Comments*, both the Wireless Innovation Forum ("WinnForum"), a membership organization "dedicated to advocating for the innovative use of spectrum and advancing radio technologies that support essential or critical communications worldwide"⁶¹, and Marcus Spectrum Solutions LLC ("MSS"), a consulting firm, raised the issue of higher spectrum. WinnForum points out,

While the *NOI* focuses on mobile use in 24-86 GHz, it also asks for input on some more general issues. Specifically, the questions in paragraph 45 focus on mmW for backhaul. While mobile technologies now under development focus on the 24-86 GHz region, there are fixed technologies that have been and are being developed for higher frequencies. For example in the 2008 Beijing Olympics, video was distributed between venues using a 120 GHz backhaul-like

⁶⁰ T. Rappaport, A. [Annamalai](#), R. Buehrer, W. Tranter "Wireless communications: past events and a future perspective", *IEEE Communications Magazine*, Volume 40 , No. 5, P. 148 – 161 (May 2002) (<http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=1006984>)

⁶¹ <http://www.wirelessinnovation.org/> WinnForum members, http://www.wirelessinnovation.org/Current_Members, include Google, Harris, NEC, NASA, several universities and several US national laboratories.

fixed service link that achieved operational data rates of 11.1 Gbps. While the Commission has frequency allocations up to 275 GHz, at present it has no service rules above 95 GHz. We urge the Commission to include spectrum above 86 GHz and above the current 95 GHz limit for fixed use by CMRS licensees for backhaul purposes. *We see no valid reason to keep bands with explicit mobile and fixed allocations empty when the technology to use them is at hand.* While footnote 64 of the NOI raises possible concerns about “coexistence with passive services” there are many bands above 95 GHz where passive service are now co-primary with both fixed and mobile allocations. The issue of co-primary allocations is not a new issue for the Commission and there are long-standing procedures to allow licensing by all classes of co-primary users while respecting the rights of others. We urge the Commission to create service rules in some of the bands above 95 GHz for backhaul to support CMRS systems.⁶² (References omitted, emphasis added)

MSS also questioned the logic of fn. 64 of the *NOI* pointing out many bands above 95 GHz where passive uses were coprimary with FIXED and MOBILE allocations and a few bands that had no passive allocations at all.⁶³ MSS went on to say

Letting spectrum lie fallow serves no public purpose. Our national competitors are funding industrial research into new technology not limited by the FCC’s present 95 GHz limit. A recent German experiment at 237 GHz that achieved speeds of 100 Gbps that was supported with partial funding from that government¹² is a good example of what is going on in other countries that is being discouraged here by the lack of service rules in the US, the apparent indifference of FCC in this area and difficulties in NTIA coordination of experimental licenses. (The German researchers have not disclosed the exact frequency and bandwidth of this test and it is likely that it included spectrum with passive primary allocations. But the nature of millimeter wave technology is such that preventing harmful interference is much easier than at lower bands.)⁶⁴

The National Academy of Sciences/National Research Council's Committee on Radio Frequencies⁶⁵ (“CORF”) pointed out in its comments,⁶⁶ there are numerous bands in the mmWave region with either exclusive passive allocations or coprimary passive allocations. The US scientific community uses these bands in US territory more intensively than many other regions do both because of the nature of US research interests, as well as the ability to build high altitude radio telescopes in arid climates due

⁶² Comments of WinnForum, Docket 14-177, Jan. 14, 2015, at p. 6

⁶³ Comments of MSS, Docket 14-177, Jan. 14, 2015, at p. 3

⁶⁴ *ibid.* at p. 5

⁶⁵ “Spectrum management activities of the U.S. National Academy of Sciences' committee on radio frequencies”, 2014 XXXIth URSI General Assembly and Scientific Symposium (URSI GASS) (<http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=6929665>)

⁶⁶ *Comments of Committee on Radio Frequencies*, Docket 14-177, January 15, 2015 (<http://apps.fcc.gov/ecfs/document/view?id=60001013670>)

to our geography. As a result of the bifurcation of US spectrum policy between the NTIA and the FCC, and the strong representation and advocacy of passive spectrum usage by National Science Foundation, National Aeronautics and Space Administration, and National Oceanographic and Atmospheric Administration within NTIA's Interdepartmental Radio Advisory Committee, accommodation with passive users is much more difficult in the US than in other countries, where the passive astronomy community does not have such a "seat at the table."

We believe responsible sharing of some of this vast mmWave spectrum, currently allocated for passive services, is in the best interest of the US economy, given our ever-increasing IT-centered economy and greater reliance on wireless communications. We note that no commenter discussed the need for the Commission to investigate a reallocation plan of the vast mmWave spectrum reserves, yet this seems prudent and vital to the future interests of the US.

Two advocates of passive spectrum usage have made comments in this proceeding. CORF has been the traditional spokesperson for all the passive scientific services, including radio astronomy and remote environmental sensing. CORF states that it

"generally supports the sharing of frequency allocations where practical, but if the Commission moves this proceeding to a rulemaking, protection of passive scientific observation must be addressed."⁶⁷

Similarly, the National Radio Astronomy Observatory ("NRAO") stated

"When the Commission proposes operating rules in the relatively uncharted mm-wave spectrum, it should consider the impact of unwanted emissions on passive service"⁶⁸

We agree with both CORF and NRAO. As fellow academicians, we believe that

⁶⁷ *Comments of CORF*, Docket 14-177, January 15, 2015, at p. 1 (<http://apps.fcc.gov/ecfs/document/view?id=60001013670>)

⁶⁸ *Reply Comments of NRAO*, Docket 14-177, January 27, 2015, at p. 3 (<http://apps.fcc.gov/ecfs/document/view?id=60001017180>)

these scientific services with long established allocations deserve and require protection in order to provide key services such as enhancing the scientific missions of radio astronomy, remote sensing, and deep space exploration. However, there is a difference between protection of actual operations, and overprotection that unnecessarily limits the productive use of a critical spectrum resource in the US that could be used to increase US international competitiveness. CORF explicitly endorses “sharing” with protection of actual passive service use. Thus, the FCC should work with all parties to develop rules for access of the spectrum above 95 GHz that respect all legitimate concerns. Particularly given the fact that international standards bodies (IEEE 802.11 and 802.15) already are working on Terahertz wireless devices (from 275 to 3,000 GHz),⁶⁹ the US must have spectrum allocations for its wireless industry to compete for products, services, and human capital.

There is no magical demarcation line at 86 or 95 GHz except in the text of present FCC rules. IEEE-USA, the US arm of the Institute of Electrical and Electronics Engineers - a technical professional society, filed a petition (“*IEEE-USA Petition*”) with the Commission in July 2013⁷⁰ seeking to determine if technology above the present regulatory limit of 95 GHz is “new technology” in the context of § 7 of the Act⁷¹ hence making it subject to a deliberation schedule, and providing a burden of proof on those who oppose the new technology. In its petition, IEEE-USA stated⁷²

IEEE-USA believes that this lack of service rules inhibits market entry for new and innovative technology and applications above 95 GHz. It also inhibits the acquisition of private sector funds for the research/development/testing necessary to move technology from technical journals into the

⁶⁹ http://standards.ieee.org/news/2013/ieee_802.15.3_sg.html

http://www.ieice.org/eng/s_issue/cfp/2015_12EC.pdf

⁷⁰ *Petition for a Declaratory Ruling*, IEEE-USA, July 1, 2013, Docket 13-259 (<http://apps.fcc.gov/ecfs/comment/view?id=6017474704>)

⁷¹ 47 U.S.C. 157

⁷² *IEEE-USA Petition* at p. 4

commercial marketplace. FCC Commissioner Pai affirmed these limitations, when he stated:

(D)elays at the Commission have substantial real-world consequences: new technologies remain on the shelves; capital lies fallow; and entrepreneurs stop hiring; or even worse, reduce their workforce, as they wait for regulatory uncertainty to work itself out. The FCC has long had a reputation in Washington as an agency that moves too slowly. (References deleted)

The FCC has apparently not resolved the issue of the *IEEE-USA Petition*. The long pendency of this petition, along with the continuing lack of rules, and lack of Commission proposals above 95 GHz, is a disincentive to capital formation for R&D in the US, even as foreign nations subsidize their own firms in this advanced technology, and help clear regulatory barriers for their “national champions.”

At present, there are many bands in the upper mmWave spectrum with only primary passive allocations.⁷³ The impact of these bands is not only their total bandwidth (which is *enormous* by today’s unlicensed and CMRS standards), but the spacing of these protected bands include large contiguous blocks of spectrum that could support practical use of for both mobile and fixed services. At the time these allocations were made -- decades ago -- such practical use of ultrawideband signals in these bands was not commercially viable. Thus, these passive allocations were based on an assumption of zero opportunity cost for the nonpassive radio services. With today’s technology, however, and the global quest for bandwidth, the opportunity cost of denying access to such spectrum is nonzero, and about to accelerate enormously. Resolution of this problem can be addressed through effective sharing between passive and nonpassive users, *e.g.* mmWave mobile, or by reconsidering the present allocations based on new information, to better balance the costs and benefits of *all* allocations for *all* services.

⁷³ There bands include 86-92 GHz, 100-102 GHz, 109.5-111.8 GHz, 114.25-116 GHz, 148.5-151.5, and 155.5-158.5 GHz

The passive community has done a good job demonstrating the benefits of passive access to these bands⁷⁴, but sharing these bands at mmWave and THz frequencies is easy to do, certainly much easier than at today's UHF/microwave bands, since highly directional steerable antennas and free space propagation path loss both work in favor of sharing. The ITU has already declined to create any new primary passive allocations above 275 GHz, recognizing that the threat of interference is less than at lower bands.⁷⁵ The secondary use of the mmWave bands with existing primary passive allocations is very different, and much more natural, to implement than that of today's lower CMRS bands.

Traditional VHF and UHF concepts for the feasibility of sharing cannot simply be extrapolated of mmWave bands. An open mind, and a true understanding of basic radio wave propagation and antenna technology is needed by all parties to explore new sharing concepts. MmWave radio astronomy is limited to a few sites in the US, due to the need for locating antennas in high arid locations. It is our understanding that most mmWave radio astronomy observations in the US take place in one site in Hawaii, two sites in California, and two sites in Arizona, even though a few other observatories have theoretical capability at these bands. Remote sensing applications are either ground-based, aircraft-based, geostationary satellite orbit (GSO) based, or Non-GSO satellite-based. All but the GSO satellite-based systems are amenable to dynamic spectrum

⁷⁴ See Committee on Scientific Use of the Radio Spectrum; Committee on Radio Frequencies; National Research Council, *Spectrum Management for Science in the 21st Century*, The National Academies Press, 2010 (<http://www.nap.edu/catalog/12800/spectrum-management-for-science-in-the-21st-century>); Panel on Frequency Allocations and Spectrum Protection for Scientific Uses, Committee on Radio Frequencies, National Research Council, *Handbook of Frequency Allocations and Spectrum Protection for Scientific Uses*, The National Academies Press, 2007 (<http://www.nap.edu/catalog/11719/handbook-of-frequency-allocations-and-spectrum-protection-for-scientific-uses>)

⁷⁵ Report ITU-R RS.2194, "Passive bands of scientific interest to EESS/SRS from 275 to 3 000 GHz", 2010 (http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-RS.2194-2010-PDF-E.pdf)

sharing concepts that are being developed in lower bands. But even GSO-based operations may be subject to sharing if quantitative sharing criteria are adopted, since fixed and mobile users do not need to illuminate the equatorial arch.

While there are real benefits in protecting radio astronomy and passive sensing bands, there are also real opportunity costs in denying access to the telecommunication industry, when ways can be found for mutually acceptable sharing. Furthermore, since our national competitors are less stringent in protecting passive spectrum allocations, a total prohibition of any emissions in any of these passive bands could possibly threaten US competitiveness. The Commission does not have to choose between protecting the passive bands and allowing advances above 95 GHz. Uses above 95 GHz have to be designed with attention to primary and coprimary passive allocations, but CORE, the most widely based representative of US passive users, has indicated a positive willingness to support consideration of new sharing approaches.

We urge the Commission to immediately start a dialogue with the passive user community and the wireless industry on sharing mechanisms, and to begin work on establishing sharing criteria between CMRS, backhaul or low-mobility (“Wi-Fi” like) systems, and existing and future passive systems, in order to make such sharing a “win-win” situation for all spectrum users while accommodating the future need for wireless bandwidth in the US.

We also recommend the Commission confer with NTIA on difficulties that experimenters might have in obtaining experimental licenses that impinge on bands with passive primary allocations⁷⁶ in cases where there is near zero technical risk of

⁷⁶ Such bands are subject to FCC/NTIA coordination under the terms of the Memorandum of Understanding between FCC and NTIA dated Jan. 31, 2003

interference. While the NTIA *Manual of Regulations and Procedures for Federal Radio Frequency Management* (“Redbook”) explicitly permits consideration of “any shared federal/non-federal frequency band or exclusive federal frequency band (to) be authorized so that non-federal developers may advance the state of technology”⁷⁷, we have heard at least one anecdotal report that the NTIA has been rejecting experimental license coordination requests that overlaps primary passive mmWave bands *regardless* of any actual interference threat to existing passive systems.⁷⁸

In summary, international competitiveness issues require the FCC to begin to dismantle the artificial spectrum ceiling that now exists at 95 GHz, so that higher frequencies may be immediately supported for wireless communications. Technologies at or above these frequencies are either here already, or are rapidly coming.⁷⁹ The continuance of this frequency ceiling, along with NTIA’s reluctance to allow experiments that offer virtually no risk of interference, threatens US leadership in wireless technology.

In the past, US leadership in allowing timely market access and spectrum access for new wireless technologies has spawned the capital formation essential for private sector wireless R&D in the US, and has helped the US remain competitive in commercial wireless technology.⁸⁰ Frequencies above 95 GHz are now in play throughout the world, and the Commission should revise its rules to enable America to compete.

While recognizing the importance of spectrum below 6 GHz, and acknowledging

(http://www.ntia.doc.gov/files/ntia/publications/fccntiamou_01312003.pdf)

⁷⁷ NTIA, *Manual of Regulations and Procedures for Federal Radio Frequency Management*, Section 8.2.27 (http://www.ntia.doc.gov/files/ntia/publications/redbook/2014-05/8_14_5.pdf)

⁷⁸ See FCC Experimental License File 1047-EX-ST-2014, Dismissal Without Prejudice Dec 1 2014 ([https://apps.fcc.gov/els/GetAtt.html?id=156210&x=.\)](https://apps.fcc.gov/els/GetAtt.html?id=156210&x=.))

⁷⁹ Since 2008 The IEEE 802.15 Terahertz Interest Group has been exploring the feasibility of Terahertz (300 GHz to 3 THz) for wireless communications. See <http://www.ieee802.org/15/pub/IGthzOLD.html>

⁸⁰ T. Rappaport, A. Annamalai, R. Buehrer, W. Tranter, “Wireless communications: past events and a future perspective”, *IEEE Communications Magazine*, Vol. 40 No. 5, p. 148 – 161 (<http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=1006984>)

the fact that international harmonization is valuable, using either of these facts as an excuse to delay *any* market access for mmWave mobile technology is not supported by statute, will play into the hands of our national competitors, and will endanger US technological leadership and access to mobile bandwidth and services. Also, as the world moves to above 100 GHz, the FCC should move similarly and swiftly.

Many mmWave spectrum bands have been identified in this proceeding, and are similarly under consideration by Ofcom. The FCC has an opportunity to act now for the benefit of the US, and can use its spectrum policy as a great equalizer for spurring new products and services that will benefit our nation.

CONCLUSIONS

NYU WIRELESS urges timely FCC action to open the mmWave spectrum above 24 GHz for mobile services. No commenter provided statutes or regulatory hurdles that warrant the delay of such action, and we demonstrated existing statutes that compel action, particularly given international competition and increasing consumer demand for capacity. While international harmonization has benefits, waiting until it is achieved (if it can ever be achieved) threatens US technological competitiveness in the face of other countries, where the governments have a more active role in financing and supporting technology through domestic regulatory actions and in the ITU. Furthermore, mmWave technology does not require international harmonization for viable products and services to be rapidly introduced, provided that many governments concurrently authorize mmWave spectrum for similar services and bandwidths. International harmonization aids commercial viability and improves market penetration rates, but should not be used as a reason to delay rulemaking.

For the licensed bands cited in the *Notice*, Table 1 shows considerations based on the existence of incumbent areas licensees, parallel with the January 2015 *Ofcom Inquiry*.

Band	Incumbent area licensees?	Common with Ofcom inquiry?
24 GHz	Yes	No
LMDS	Yes	Yes
39 GHz	Yes	Yes
37/42 GHz	No	No
70/80 GHz	No	Yes

Table 1: Bands considered for early FCC actions

The LMDS and 39 GHz bands each have incumbent licensees and are common with Ofcom’s current inquiry. Thus, we recommend these bands for near term rulemaking action.

Where there are areas without existing licensees, the Commission should consider licensing them in a timely way. Technical rules for mobile should provide unprecedented bandwidths, should focus primarily on avoiding interference to other licensees, and can be similar to existing fixed rules, but with loosening of regulations to permit mobile or Wi-Fi like services, while relaxing the stringent fixed beam antenna specifications (see our *Comments*). RF safety rules exist in these bands, but require some clarification and modification to determine compliance in the case of high gain adaptive antennas close to the user - as we discussed in our *Comments*.⁸¹

⁸¹ *Comments of NYU WIRELESS, op. cit.*, at p. 46-51

There are no major barriers for making the 64-71 GHz band available for unlicensed use now, other than protecting yet unused allocations for satellite services, such as ISS, in this band. Therefore, we recommend timely action on making 64-71 GHz available for unlicensed use.

We also urge timely action on service rules for the 24 and 42 GHz bands which already have mobile allocations, with very wide channel bandwidths wherever possible. We recognize that the lack of current licensees at 42 GHz, and the small geographic area already licensed at 24 GHz, will delay access to these bands, but the sooner the Commissioner starts, the sooner service will be available and the better it will be for US competitiveness.

We urge timely action that expands the mmWave spectrum for mobile use, and urge expansion of unlicensed bands and new regulations for the frequency ranges above 100 GHz, so as to provide a technical playground will allow the US wireless industry to be competitive in the global move to mmWave and THz frequencies.

We commend the Commission on this proceeding, and thank the Commission for its consideration of these comments and for the opportunity to participate.

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